

# Hybrid Vehicle Systems Optimization using ADVISOR and iSIGHT

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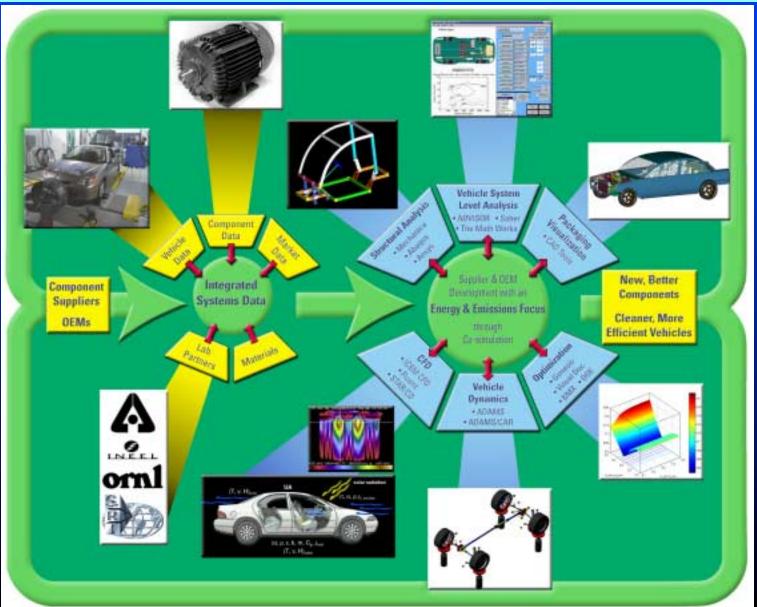
#### **Outline**

- Digital Functional Vehicle Vision
- ADVISOR Overview
- iSIGHT-ADVISOR Application
- Results Discussion
- Conclusions and Future Plans





## **Overall Vision: Digital Functional Vehicle**





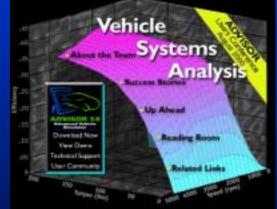


### **Background on ADVISOR**

- ADVISOR = ADvanced Vehicle SimulatOR
  - simulates conventional, electric, or hybrid vehicles (series, parallel, or fuel cell)
- ADVISOR was created in 1994 to support DOE Hybrid

Program at NREL

 Released on vehicle systems analysis web site in September, 1998

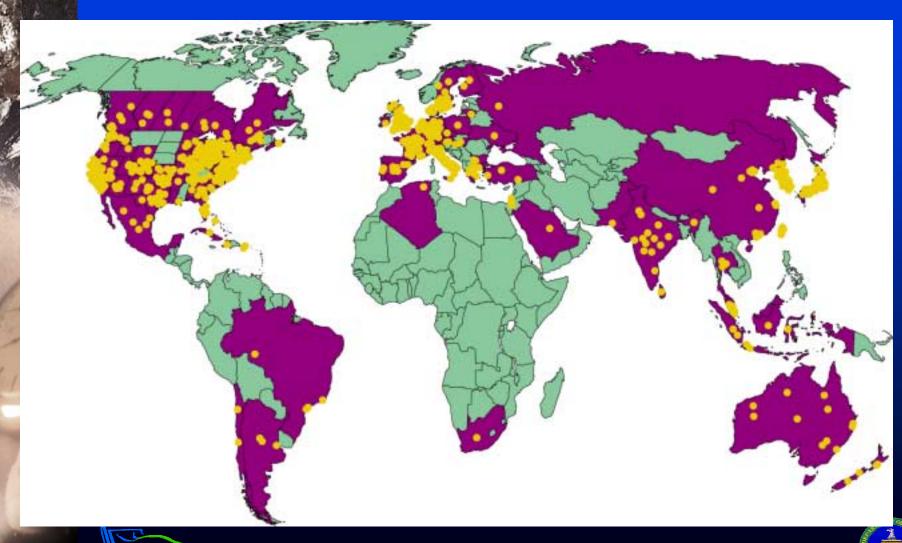


- Downloaded by over 3400 people around world
- Users help provide component data and validation, feedback for future development

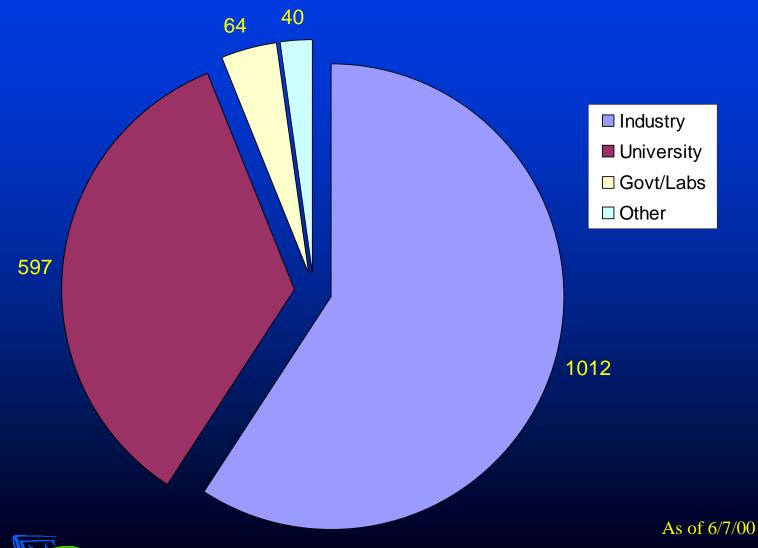




# ADVISOR Being Used Globally April 2001: >3400 users



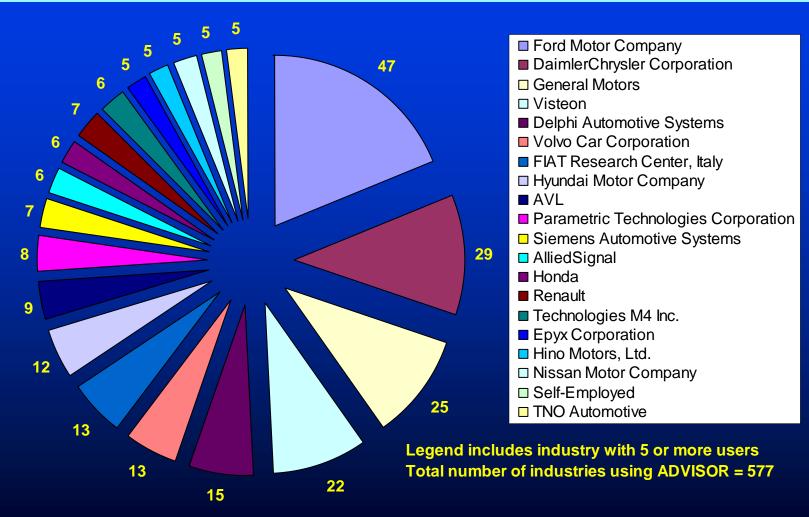
# **ADVISOR Downloads by Type of Organization**



NREL, Center for Transportation Technologies and Systems



### **ADVISOR Downloads by Industry**

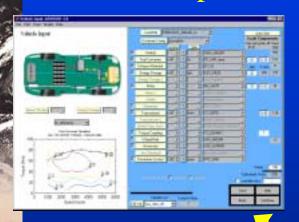




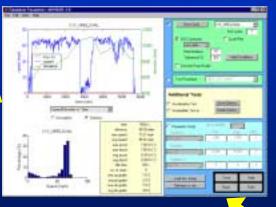


## Three Main ADVISOR Screens (Roadmap)

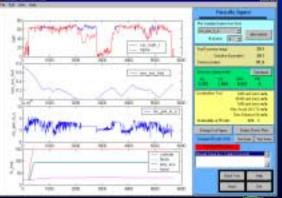
#### Vehicle Input



#### Simulation Setup



#### Results







#### Types of Simulation Tests Possible Parametric sweeps **Drive cycles** 60 Acceleration and grade tests **Control Strategy** Optimizations. / ssem, riev CYC FUDS 0 DS 200 0-60 mph (sec): 12.3 150 40-60 mph (sec): 5.8 튣 100 0-85 mph (sec): 24.6 50 GIES AND SYSTEMS 10 15 20



#### **Problem Definition**

- Objective
  - Maximize fuel economy of fuel cell powered hybrid electric SUV
- Constraints
  - Performance equivalent to comparable conventional vehicle
    - 7 inequality constraints
- 8 Total Design Variables
  - 4 Component Characteristics
     4 Control Strategy
    - fuel cell peak power
    - traction motor peak power
    - number of battery modules
    - capacity of battery modules

- - low power fuel cell power cut-off
  - high power fuel cell power cut-off
  - minimum fuel cell off time
  - charge power set point







### **Current Implementation**

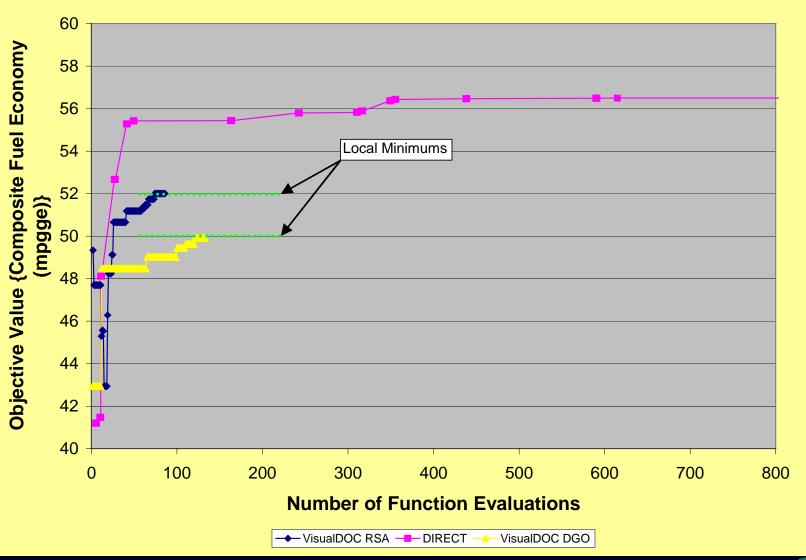
- 2 step process
  - adjust component characteristics
    - guess control parameter settings
  - adjust control parameters
- With optimization tools
  - all in one step!

And the second second second	Control Strateg	y Optimization Me	had Selection	
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F ESS (# modules)	25 19 29			
Motor Size (KW)	75 56 112			
Low SOC (-)				
☐ High SOC (+)				
Final Drive Rates ==> min.	pb sheet (aby) 30			
	Objectives			
Component Sizes Message				
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VisualDBC	Optimization Parameters			
Design Cycles	Mrs Max 25			
Optimization Method: @ ( ) or				
- Response surface approxima	sioni nefrod will be used.			
PUN DEFAUI	TS CANCEL HELF			



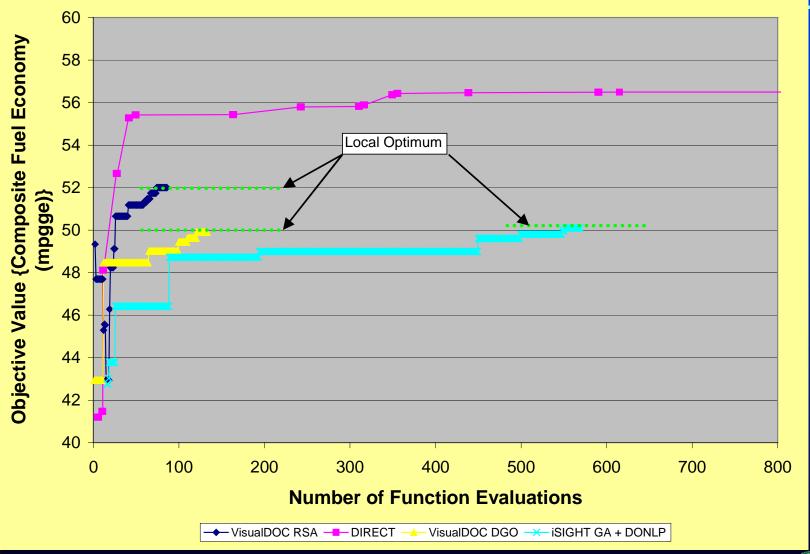
### **Recent Application of Other Optimization Tools**







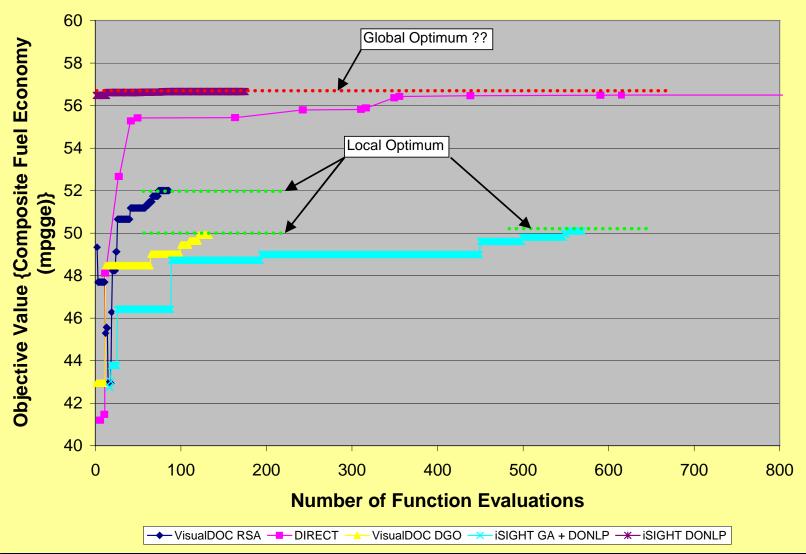
### iSIGHT Starting from initial conditions ...







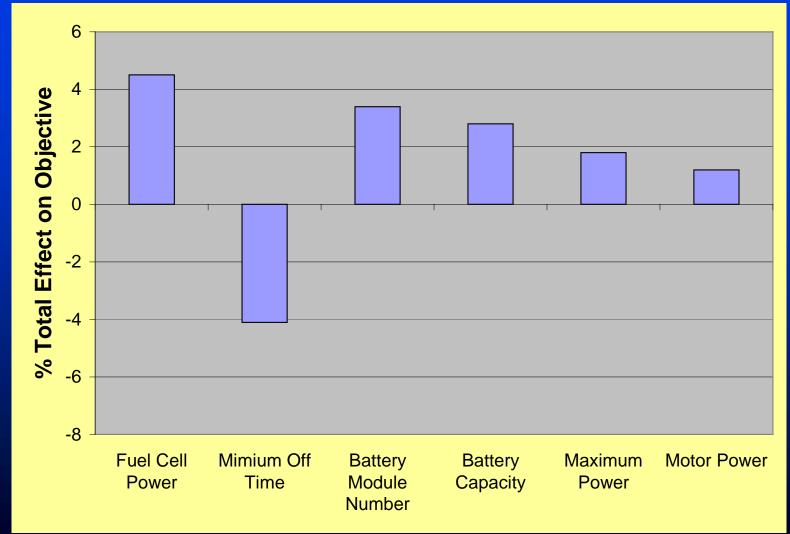
### iSIGHT Starting from best known conditions ...







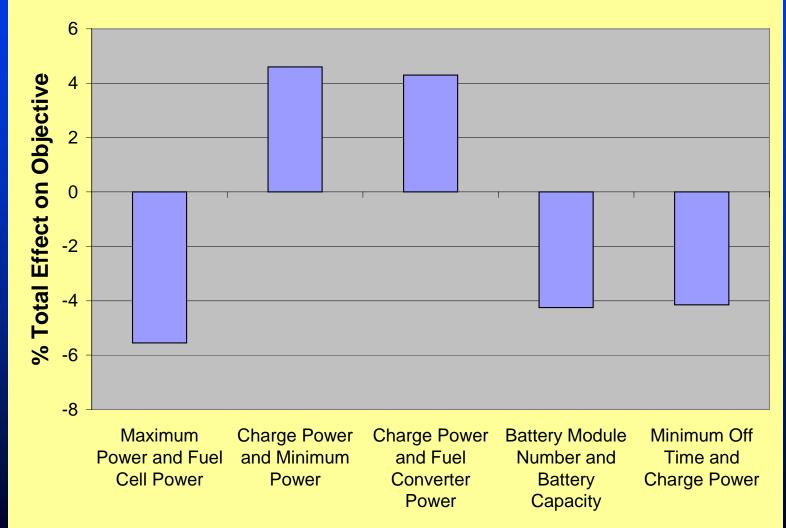
## **DOE Results - Leading Individual Effects**







## Interactions more influential than individual effects! DOE Results - Leading Interactions









# Top Five Design Parameters Identified by DOE Using iSIGHT

- Charge Power
- Maximum Power
- Fuel Converter Power
- Minimum Power
- Battery Capacity











## **Multi-Algorithm Approach**

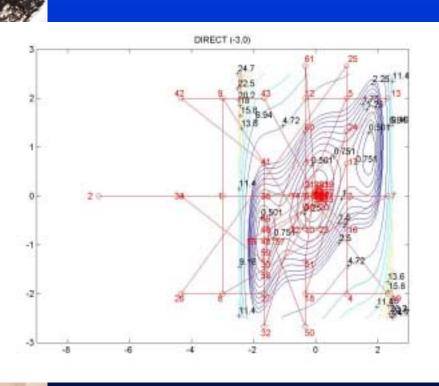


- Efficient solution method
- Ability to automate in iSIGHT
- Increased likelihood of finding global optimum
- Especially Effective on noisy/discontinuous/ infeasible design spaces





# DIRECT for Locating Local Optimum Regions



- DIRECT is an algorithm that searches both locally and globally
- Restart functionality at any time
- Initially proposed by Donald R. Jones
- Limited to small number of design variables
- Great potential for parallelization

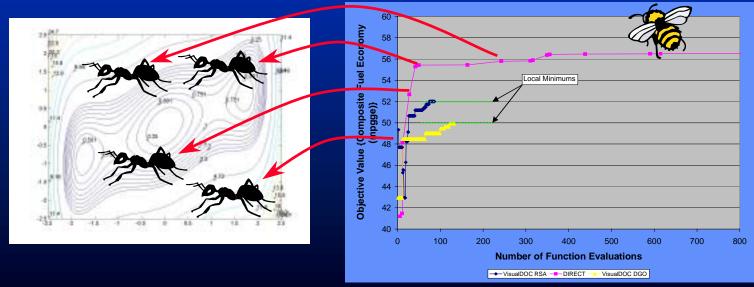






## Parallel Processing of Gradient and Non-Gradient Based Solutions

- Use non-gradient based algorithm (the bee) to generate start conditions
- Spawn new gradient based processes (the ants) at each change in design iteration
- Process both gradient and non-gradient solutions in parallel
- Choose best of multiple solutions









#### **Conclusions**

- Identification of critical parameters of fuel cell powered hybrid electric SUV is very challenging
  - Large number of variables
  - Very little experimental data
  - Strong coupling between the parameters (factors)
  - Effect of most factors on fuel economy is non-monotonic
- Ignoring the coupling leads to faulty conclusions
- Combination of system analysis tools (ADVISOR) and modern optimization tools (iSIGHT) is key in hybrid vehicle design studies







### **Future Plans**

- Improved communication mechanism between iSIGHT and MATLAB
- Multi-objective design optimization with multidisciplinary CAE (Digital Functional Vehicle)
- Distributed/parallel processing
- Experimental verification of assumptions, conclusions and results
- Identification of industry partner for collaboration and identification of additional objectives







# 2001 Joint ADVISOR/PSAT Vehicle Systems Modeling User Conference

August 28-29, 2001

@ USCAR Southfield, Michigan

Focus Areas

Optimization

**Control Strategy** 

Hybrid Powertrain

Fuel Cells

**Model Validation** 

www.nrel.gov/transportation/analysis/conference.html



